Rhode Island Stormwater Quality Manual
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Acknowledgements

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Chapter One - Introduction

1.1 Purpose of the Manual

The purpose of this manual is to provide guidance on the measures necessary to protect the waters of the State of Rhode Island from the adverse impacts of postconstruction stormwater runoff. The guidance provided in this manual is applicable to new development, redevelopment, and upgrades to existing development. The manual focuses on site planning, source control and pollution prevention, and stormwater treatment practices. Related topics such as erosion and sediment control, stormwater drainage design and flood control, and watershed management are addressed in the manual as secondary considerations. Additional information on these topics can be found in other related guidance documents listed at the end of this chapter. The manual does not address agricultural runoff.

1.2 Applicability of the Manual

This manual has been prepared to assist property owners, developers, engineers, consultants, contractors, municipal planners and others in planning and designing effective stormwater best management practices. The material contained within the manual is provided as guidance to those persons involved in the development of properties, many of which will be subject to state and local regulatory permit requirements. This manual should be used by applicants to:

- Coastal Resources Management Council (CRMC).
- Department of Environmental Management (DEM).
- Local municipalities that have stormwater ordinances.

Municipal officials, including planners and engineers, can use the manual to support local stormwater management programs. This may include incorporating or referencing the manual into local ordinances.

The design practices described in this manual should be implemented by an individual with a demonstrated level of professional competence, such as a professional engineer licensed to practice in the State of Rhode Island. Design engineers, as well as those responsible for operation and maintenance, are ultimately responsible for the long-term performance and success of these practices. However, the use of this manual is not restricted to engineers or technical professionals. It is also intended for use by other individuals involved in stormwater and land use management for reviewing and recommending practices contained in the manual.

DEM currently administers a number of programs that require stormwater management. Depending on site conditions and how stormwater is managed, different regulations apply. The CRMC also has stormwater management requirements that apply to projects located within that agency's jurisdiction. This manual should be used by applicants to the DEM and CRMC. Applicants are encouraged to adhere to the recommended design and performance criteria in this manual. Where an applicant deviates from the design standards, a technical justification may be required by the permitting entity. Use of the manual does not relieve an applicant from complying with other applicable regulatory requirements. As mentioned above, certain criteria outlined in this manual may be made mandatory via amendments to existing regulations.

Applicants are encouraged to utilize the following publications to assist in designing appropriate best management practices for the proposed development: the latest edition of the Rhode Island Soil Erosion and Sediment Control Handbook (available from the USDA Natural Conservation Service or DEM Office of Technical and Customer Assistance).

To ensure that the project meets the state's regulatory requirements, applicants should consult DEM freshwater wetlands, water quality, Rhode Island Pollutant Discharge Elimination System (RIPDES), and under ground injection control regulations. Applicants should also consult the *Rhode Island Coastal Resources Management Program* and applicable special area management plans (e.g., *Rhode Island's Salt Pond Region: A Special Area Management Plan* and the *Narrow River Special Area Management Plan*) if the project is located within CRMC jurisdiction. In addition, applicants should consult with their local building official in order to identify any local stormwater management or erosion and sediment control ordinances.

For further information contact:

Rhode Island Department of Environmental Management 401-222-4700
235 Promenade Street
Providence, RI 02908

- Office of Water Resources
- Freshwater Wetlands Program
- Water Quality Certification Program
- RIPDES Program
- Underground Injection Control Program

Rhode Island Coastal Resources Management Council 401-783-3370
Oliver Stedman Government Center
Tower Hill Road
Wakefield, RI 02879

1.3 Organization of the Manual

The manual is organized into two volumes, both contained in a single, comprehensive document. The organization of the manual generally follows the recommended stormwater management planning process, which emphasizes preventative measures such as site planning and alternative site design, source controls, and pollution prevention over end-of-pipe structural controls.

- **Chapter One – Introduction**
  Chapter one describes the purpose of the manual and its applicability as well as the general organization of the manual.

- **Chapter Two – Why Stormwater Matters: The Impacts of Urbanization**
  This chapter introduces the concept of urban stormwater runoff and its impact on watershed hydrology, water quality, and ecology. Chapter Two summarizes why stormwater management measures are necessary to protect receiving waters from the adverse impacts of uncontrolled stormwater runoff.

- **Chapter Three – Approaches for Preventing and Mitigating Stormwater Impacts**
  Chapter Three presents an overview of approaches for preventing and mitigating stormwater impacts through site planning and pollution prevention, stormwater quantity controls, construction erosion and sedimentation controls, and post-construction stormwater quality management.

- **Chapter Four – Nonstructural and Small-Scale Upland Management**
  Chapter Four addresses the use of such techniques as better site design and low impact development. These techniques should be incorporated into the design of new and retrofit projects to retain stormwater on-site and reduce reliance on end-of-pipe practices.

- **Chapter Five – Source Control Practices and Pollution Prevention**
  Chapter Five describes source control and pollution prevention practices to limit the generation of stormwater pollutants at their source. This chapter focuses on common municipal, residential, commercial, and industrial practices applicable to new and existing development such solid waste containment, hazardous materials containment, septic system management and lawn care and landscaping practices.

- **Chapter Six – Innovative and Emerging Technologies**
  Chapter Six describes general categories of recently developed, emerging, or potential future stormwater treatment devices and technologies, as well as criteria for evaluating the performance and applicability of new treatment practices.

- **Chapter Seven – Hydrologic Sizing Criteria for Stormwater Treatment Practices**
  Chapter Seven explains the procedures and applicability of sizing criteria for structural stormwater treatment practices to meet pollutant reduction, groundwater recharge and runoff volume reduction, and peak flow control requirements. This chapter also includes guidance on the design of stormwater bypass structures and sizing examples for various types of stormwater treatment practices.

- **Chapter Eight – Selection Criteria for Stormwater Treatment Practices**
  Chapter Eight provides guidance on selecting appropriate structural stormwater treatment practices for a development site based on the requirements and needs of the site. This chapter includes a recommended selection process and selection criteria.

- **Chapter Nine – Developing a Site Stormwater Management Plan**
  Chapter Nine describes how to prepare a site stormwater management plan for review by local and state regulatory agencies. The chapter includes a recommended plan format and contents, and a completeness checklist for use by the plan preparer and reviewer.

- **Chapter Ten – Stormwater Retrofits**
  Chapter Ten describes techniques for retrofitting existing developed sites to improve or enhance the water quality mitigation functions of the sites. Chapter Ten also discusses the conditions for which stormwater retrofits are appropriate and the potential benefits of stormwater retrofits.

- **Chapter Eleven – Design Guidance for Stormwater Treatment Practices**
  Chapter Eleven provides detailed technical design guidance for each of the stormwater treatment practices introduced in Chapter Six. This chapter includes guidance on the design, construction, and maintenance of these practices, as well as summary information on selection and sizing criteria addressed in previous chapters.

- **Appendices**
  Appendices containing supplemental information on the design, construction, and maintenance of structural stormwater management practices are included at the end of Volume II. A glossary of terms used in the manual is also provided at the end of Volume II.

While providing detailed guidance on a number of recommended stormwater management practices and related topics, this document is not an exhaustive reference on each topic and does not address all aspects of stormwater management. Additional technical guidance can be found in numerous other documents, many of which are referenced in this manual. References and recommended additional sources of information are listed at the end of each chapter.

Additional Information Sources

Watershed Management

Center for Watershed Protection. 2000. *The Practice of Watershed Protection*, Ellicott City, Maryland.

Davenport, T.E. 2002. The Watershed Project Management Guide. Lewis Publishers/CRC Press.

U.S. Environmental Protection Agency, Office of Water. 2001. *Protecting and Restoring America's Watersheds: Status, Trends, and Initiatives in Watershed Management.* EPA-840-R-00-001.

Nonpoint Source Management

U.S. Environmental Protection Agency, Office of Water. 1993. *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters*.

U.S. Department of Agriculture, Natural Resources Conservation Service. *National Handbook of Conservation Practices*.

Drainage Design and Flood Control

Natural Resource Conservation Service (formerly Soil Conservation Service). 1986. *Urban Hydrology for Small Watersheds, TR-55*.

Water Environment Federation (WEF) and American Society of Civil Engineers (ASCE). 1992. *Design and Construction of Urban Stormwater Management Systems (Urban Runoff Quality Management (WEF Manual of Practice FD-20 and ASCE Manual and Report on Engineering Practice No. 77)*.

Erosion and Sediment Control

Rhode Island Department of Environmental Management, USDA Soil [Natural Resources] Conservation Service and Rhode Island State Conservation Committee. 1989. *Rhode Island Soil Erosion and Sediment Control Handbook.*

Chapter Two – Why Stormwater Matters: The Impacts of Urbanization

2.1 What is Stormwater Runoff?

Figure 2.1-a Intensity of stormwater runoff increases with intensity of land development.

Stormwater runoff is precipitation that washes over the land (i.e., runs off) to replenish nearby streams, lakes, wetlands, estuaries and other waters. Water that does not runoff is sometimes referred to as "abstracted." Abstraction includes three primary mechanisms: (a) atmospheric evaporation; (b) transpiration or uptake by plants, which in combination with evaporation is referred to as evapotranspiration; and (c) soil infiltration, which is responsible for groundwater recharge. Thus stormwater runoff is essentially the leftover water after abstraction.

Stormwater runoff is a part of the hydrologic cycle (the movement of water between the earth's atmosphere, land, and waterbodies). A schematic of the hydrologic cycle is shown in Figure 2.1-b.

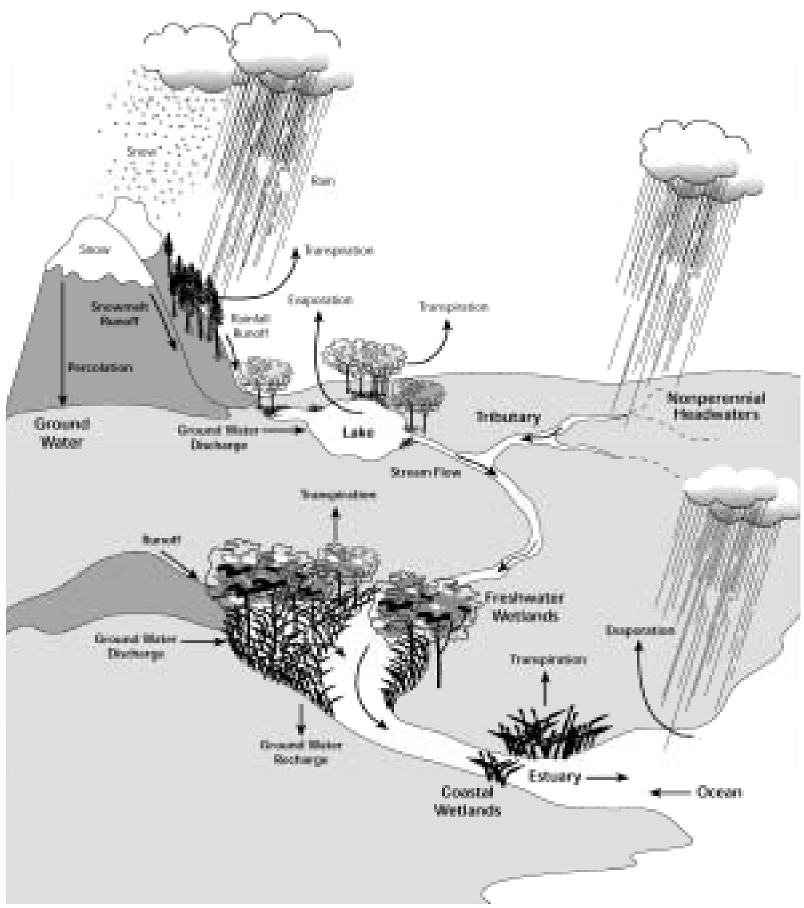
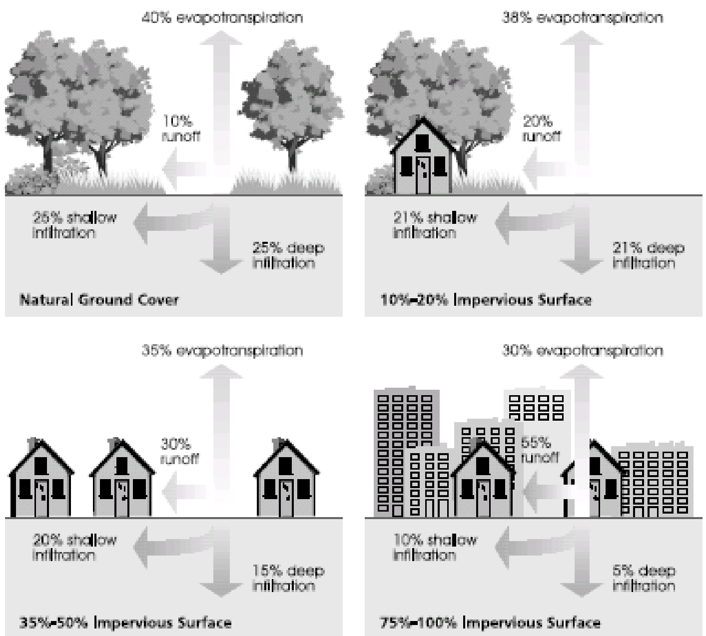


Figure 2.1-b Hydrologic cycle. Source: Adapted from Connecticut, 2004.

Urbanization

However, when land is developed with buildings, roads and walkways, the development interrupts abstraction mechanisms, prevents the retention of precipitation and a greater fraction of stormwater runs off. One way to express the intensity of land development is by measuring the percentage of land covered with impervious surface (i.e., primarily pavement and buildings). Figure 2.1-c below illustrates how increasing degrees urbanization may disrupt the hydrologic cycle and reduce the land's capacity to abstract stormwater.



Impervious cover also provides a good measure of the overall health of a watershed. Numerous studies have documented the cumulative effects of urbanization on stream and watershed ecology (Schueler et al., 1992; Schueler, 1994; Schueler, 1995; Booth and Reinelt, 1993, Arnold and Gibbons, 1996; Brant, 1999; Shaver and Maxted, 1996). Research has shown that when impervious cover in a watershed reaches between 10 and 25 percent, ecological stress becomes clearly apparent. Beyond 25 percent, stream stability is reduced, habitat is lost, water quality becomes degraded and biological diversity decreases (NRDC, May 1999).

To put these thresholds into perspective, typical imperviousness in medium-density residential areas ranges from 25 to nearly 60 percent (SCS, 1986). Table 2.1-1 indicates typical percentages of impervious cover for various land uses in according to TR-55. While most watersheds are developed with land uses of varied intensity, significant residential, commercial and industrial development suggests an expanse of impervious cover that exceeds ecological stress thresholds.

Table 2.1-2
Typical Impervious Coverage of Land Uses

Land Use	**Percent Impervious Cover**
Commercial and Business District	85
Industrial	72
High Density Residential (i.e., 1/8 ac zoning)	65
Medium-High Density Residential (i.e., 1/4 ac zoning)	25
Medium-Low Density Residential (i.e., 1/2 ac zoning)	38
Low Density Residential (i.e., 1 ac zoning)	20

Source: Adapted from USDA Soil Conservation Service, 1986.

2.2 Urbanization and Stormwater Impacts

Stormwater from urban development can create severe impacts to downstream waters and waterways. These impacts can be broken down into four types, which include:

1. Changes to stream flow.
2. Changes to stream geometry.
3. Water quality impacts.
4. Degradation of aquatic habitat.

The following discussion lists and describes these impacts to illustrate why effective stormwater management is needed to address and mitigate them.

Changes to Stream Flow

Urban development disrupts the natural water cycle tends to intensify runoff. Intensified runoff results in:

- *Increased Runoff Volumes* –Replacement of natural features (e.g., woodlands) with buildings, pavement and lawns can dramatically increase the total volume of water running off into streams of developed watersheds.
- *Increased Peak Runoff Discharges* – Increased runoff volumes result in increased peak discharges. Peak discharges for a developed watershed can be two to five times higher than those for an undisturbed watershed.
- *Greater Runoff Velocities* – Impervious surfaces, compacted soils and storm sewers are more hydraulically than natural landscapes and tend to increase the speed at which rainfall runs off land surfaces within a watershed.
- *Time of Concentration* – As runoff velocities increase run off takes less time to reach streams or other waterbodies.
- *Increased Frequency of Bank-Full and Near Bank-Full Events*–Increased runoff volumes and peak flows increase the frequency and duration of flows that cut (i.e., widen and deepen) stream channels.
- *Increased Flooding*–Increased runoff volumes and peaks increase the frequency, duration and severity of flows that overtop stream banks and cause flooding.
- *Lower Dry Weather Flows (Base Flow*)– Stream base flow (i.e., the typical level of stream flow during dry weather) arises primarily from groundwater. Loss of stormwater abstraction reduces groundwater recharge, artificially lowers the groundwater table and consequently lowers base flow.

Figure 2.2-a depicts typical predevelopment and postdevelopment stream flow hydrographs for a developed watershed.

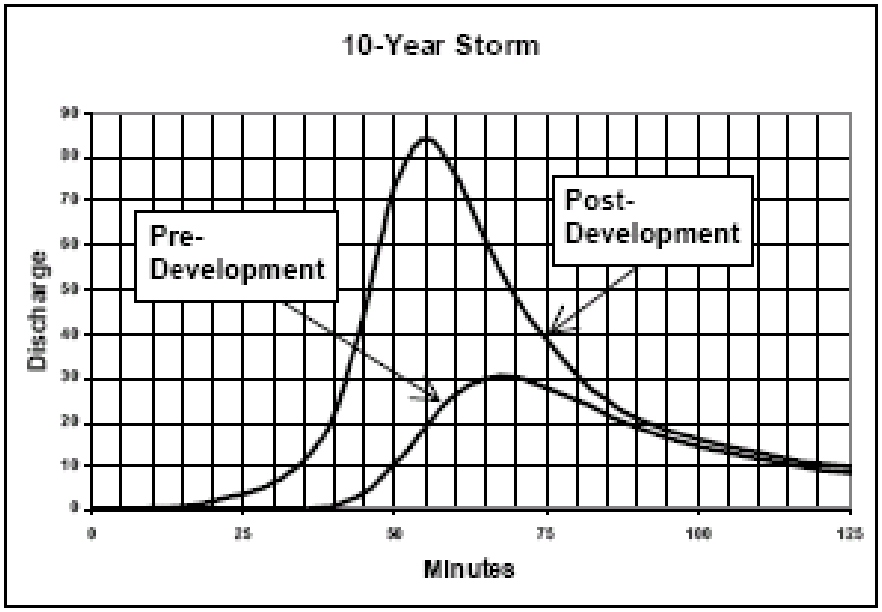


Figure 2.2-a Predevelopment and postdevelopment stream flow hydrographs for a developed watershed.

Changes to Stream Geometry

The changes in the rates and amounts of runoff from developed watersheds directly affect the morphology, or physical shape and character, of streams and rivers. Some of the impacts due to urban development include:

- *Stream Widening and Bank Erosion*–Stream channels widen to accommodate and convey the increased runoff and higher stream flows from developed areas. More frequent small and moderate runoff events undercut and scour stream banks causing steeper banks to slump and collapse during larger storms. A stream can widen many times its original size due to postdevelopment runoff.
- *Streambed Downcutting* – Streams may also deepen to accommodate higher flows. Deepened streams are less stable. When streams downcut, their bottom widths may decrease (i.e., thin). Loss of width compresses flow and increases flow velocity triggering further channel erosion both upstream and downstream.
- *Loss of Riparian Trees* –Increased flows undercut stream banks and cause them to slump, trees that protect the banks are exposed at the roots and may eventually topple over. Roots systems support soil structure. Unanchored stream banks erode away more easily.
- *Sedimentation of Channel Beds* – When upstream channels erode, sediment particles are carried and deposited downstream. The deposits replace the natural streambed with shifting sands, silts and muck.
- *Increased Floodplain Elevation* –Floodplains are areas adjacent to streams that become inundated during peak storm events. A stream's floodplain elevation (i.e., height above sea level) typically increases with intensity of development and runoff volume. Increases

become more acute when building and filling occurs in floodplain areas where it may displace floodwaters and directly elevate the floodplain.

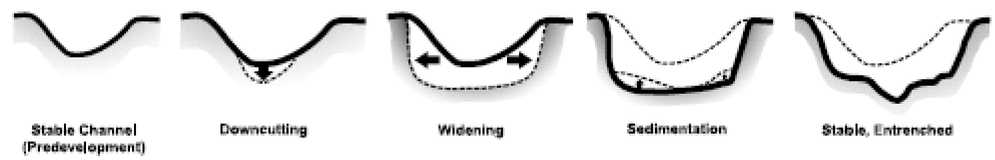


Figure 2.2-b Changes to a stream's physical character due to watershed development. Source: Adapted from Atlanta Regional Commission, 2001.

Water Quality Impacts

Development concentrates and increases the amount of these nonpoint source pollutants. As stormwater runoff moves across the land surface, it picks up and carries away both natural and human-made pollutants, depositing them into Rhode Island's streams, rivers, lakes, wetlands, coastal waters and marshes, and groundwater. Stormwater pollution is one of the leading sources of water quality degradation in Rhode Island. Water quality degradation in urbanizing watersheds starts when development begins. Erosion from construction sites and other disturbed areas contribute large amounts of sediment to streams. As construction and development proceed, impervious surfaces replace the natural land cover and pollutants from human activities begin to accumulate on these surfaces. During storm events, these pollutants are then washed off into the streams. Stormwater also causes discharges from sewer overflows and leaching from septic tanks. There are a number of other causes of nonpoint source pollution in urban areas that are not specifically related to wet weather events including leaking sewer pipes, sanitary sewage spills, and illicit discharge of commercial/industrial wastewater and wash waters to storm drains.

Table 2.2-1 summarizes the major stormwater pollutants and their effects. Some of the most frequently occurring pollution impacts and their sources for urban streams are:

Table 2.2-1
Effects of Stormwater Pollutants

Stormwater Pollutant	Effects
Sediments—Suspended Solids,Dissolved Solids, Turbidity	• Stream turbidity Habitat changes • Recreation/aesthetic loss • Contaminant transport • Filling of lakes and reservoirs
Nutrients—Nitrate, Nitrite, Ammonia, Organic Nitrogen, Phosphate, Total Phosphorus	• Algae blooms • Eutrophication • Ammonia and nitrate toxicity • Recreation/aesthetic loss
Microbes—Total and Fecal Coliforms, Fecal Streptococci, Viruses, E.Coli, Enterocci	• Ear/Intestinal infections • Shellfish bed closure • Recreation/aesthetic loss
Organic Matter—Vegetation, Sewage, Other Oxygen Demanding	• Dissolved oxygen depletion • Odors Fish kills

Materials	
Toxic Pollutants—Heavy Metals (cadmium, copper, lead, zinc), Organics, Hydrocarbons, Pesticides/Herbicides	• Human & aquatic toxicity • Bioaccumulation in the food chain
Thermal Pollution	• Dissolved oxygen depletion • Habitat changes
Trash and debris	• Recreation/aesthetic loss

- *Reduced Oxygen in Streams*–The decomposition process of organic matter uses up dissolved oxygen (DO) in the water, which is essential to fish and other aquatic life. As organic matter is washed off by stormwater, dissolved oxygen levels in receiving waters can be rapidly depleted. If the DO deficit is severe enough, fish kills may occur and stream life can weaken and die. In addition, oxygen depletion can affect the release of toxic chemicals and nutrients from sediments deposited in a waterway.

  All forms of organic matter in urban stormwater runoff such as leaves, grass clippings and pet waste contribute to the problem. In addition, there are a number of non-stormwater discharges of organic matter to surface waters such as sanitary sewer leakage and septic tank leaching.

- *Nutrient Enrichment*–Runoff from urban watersheds contains increased nutrients such as nitrogen or phosphorus compounds. Increased nutrient levels are a problem as they promote weed and algae growth in lakes, streams and estuaries. Algae blooms block sunlight from reaching underwater grasses and deplete oxygen in bottom waters. In addition, nitrification of ammonia by microorganisms can consume dissolved oxygen, while nitrates can contaminate groundwater supplies. Sources of nutrients in the urban environment include washoff of fertilizers and vegetative litter, animal wastes, sewer overflows and leaks, septic tank seepage, detergents, and the dry and wet fallout of materials in the atmosphere.

- *Microbial Contamination*–The level of bacteria, viruses and other microbes found in urban stormwater runoff often exceeds public health standards for water contact recreation such as swimming and wading. Microbes can also contaminate shellfish beds, preventing their harvesting and consumption, as well as increasing the cost of treating drinking water. The main sources of these contaminants are sewer overflows, septic tanks, pet waste, and urban wildlife such as pigeons, waterfowl, squirrels, and raccoons.

- *Hydrocarbons*–Oils, greases and gasoline contain a wide array of hydrocarbon compounds, some of which have shown to be carcinogenic, teratogenic and mutagenic in certain species of fish. In addition, in large quantities, oil can impact drinking water supplies and affect recreational use of waters. Oils and other hydrocarbons are washed off roads and parking lots, primarily due to engine leakage from vehicles. Other sources include the improper disposal of motor oil in storm drains and streams, spills at fueling stations and restaurant grease traps.

- *Toxic Materials*–Besides oils and greases, urban stormwater runoff can contain a wide variety of other toxicants and compounds including heavy metals such as lead, zinc, copper, and cadmium, and organic pollutants such as pesticides, PCBs, and phenols. These contaminants are of concern because they are toxic to aquatic organisms and can bioaccumulate in the food chain. In addition, they also impair drinking water sources and human health. Many of these toxicants accumulate in the sediments of streams and lakes. Sources of these contaminants include industrial and commercial sites, urban surfaces such as rooftops and painted areas, vehicles and other machinery, improperly disposed household chemicals, landfills, hazardous waste sites and atmospheric deposition.

- *Sedimentation*–Eroded soils are a common component of urban stormwater and are a pollutant in their own right. Excessive sediment can be detrimental to aquatic life by interfering with photosynthesis, respiration, growth and reproduction. Sediment particles transport other pollutants that are attached to their surfaces including nutrients, trace metals and hydrocarbons. High turbidity due to sediment increases the cost of treating drinking water and reduces the value of surface waters for industrial and recreational use. Sediment also fills ditches and small streams and clogs storm sewers and pipes, causing flooding and property damage. Sedimentation can reduce the capacity of reservoirs and lakes, block navigation channels, fill harbors and silt estuaries. Erosion from construction sites, exposed soils, street runoff, and stream bank erosion are the primary sources of sediment in urban runoff.

- *Higher Water Temperature*–As runoff flows over impervious surfaces such as asphalt and concrete, it increases in temperature before reaching a stream or pond. Water temperatures are also increased due to shallow ponds and impoundments along a watercourse as well as fewer trees along streams to shade the water. Since warm water can hold less dissolved oxygen than cold water, this “thermal pollution” further reduces oxygen levels in depleted urban streams. Temperature changes can severely disrupt certain aquatic species, such as trout and stoneflies, which can survive only within a narrow temperature range.

- *Trash and Debris*–Considerable quantities of trash and other debris are washed through storm drain systems and into streams, lakes and bays. The primary impact is the creation of an aesthetic “eyesore” in waterways and a reduction in recreational value. In smaller streams, debris can cause blockage of the channel, which can result in localized flooding and erosion.

Concentrations of pollutants in stormwater runoff vary considerably between sites and storm events. Typical average pollutant concentrations in urban stormwater runoff in the Northeast United States are summarized in Table 2.2-2.

Table 2.2-2
Average Pollutant Concentrations in Urban Stormwater Runoff

Constituent	Units	Concentration
Total Suspended Solids[1]	mg/l	54.5
Total Phosphorous[1]	mg/l	0.26
Soluble Phosphorous[1]	mg/l	0.10
Total Nitrogen[1]	mg/l	2.00
Total Kjeldahl Nitrogen[1]	mg/l	1.47
Nitrite and Nitrate[1]	mg/l	0.53
Copper[1]	μg/l	11.1
Lead[1]	μg/l	50.7
Zinc[1]	μg/l	129
BOD[1]	mg/l	11.5
COD[1]	mg/l	44.7
Organic Carbon[2]	mg/l	11.9
PAH[3]	mg/l	3.5
Oil and Grease[4]	mg/l	3.0
Fecal Coliform[5]	Colonies/100 ml	15,000
Fecal Strep[5]	Colonies/100 ml	35,400
Chloride (snowmelt)[6]	mg/l	116

Source: Adapted from NYDEC, 2001; original sources are listed below.
[1]Pooled NURP/USGS (Smullen and Cave, 1998)
[2]Derived from National Pollutant Removal Database (Winer, 2000)
[3]Rabanal and Grizzard, 1996
[4]Crunkilton et al., 1996
[5]Schueler, 1999
[6]Oberts, 1994
mg/l = milligrams per liter
μg/l= micrograms per liter

Impacts to Aquatic Habitat

Along with changes in stream hydrology and morphology, the habitat value of streams may diminish due to development. Aquatic habitat impacts include:

- *Degradation of Habitat Structure* – High velocity flows scour channels and may wash away entire biological communities. Stream bank erosion and the loss of riparian vegetation reduce habitat for fish and other aquatic life, while sediment deposits may smother bottom-dwelling organisms.
- *Loss of Pool Riffle Structure* – Streams draining undeveloped watersheds often contain pools of deeper, more slowly flowing water that alternate with "riffles" or shoals of shallower, fast-flowing water. These pools and riffles provide valuable habitat for fish and aquatic insects. As a result of the increased flows and sediment loads from urban watersheds, the pools and riffles disappear and are replaced with more uniform, and

often shallower, streambeds that provide less varied habitat and may fail to support a native diversity of species.

- *Reduce Base flows* – Urbanization reduces the groundwater recharge and consequently the base flow to streams. Loss of flow stresses habitat and may eliminate many species. During periods of drought streams may dry up completely, extirpating even the hardiest plants and animals.
- *Increased Stream Temperature* –Pavement tends to absorb light energy as heat. Precipitation over pavement absorbs the heat as it runoffs into nearby streams and stream temperature. Increased temperatures can reduce dissolved oxygen levels and disrupt the food chain. Certain aquatic species can only survive within a narrow temperature range.
- *Decline in Abundance and Biodiversity* – Loss of habitat and habitat variety reduces abundance and diversity of organisms.

The majority of research on the ecological impacts of urbanization has focused on streams. However, urban stormwater runoff has also been shown to adversely impact other receiving environments such as wetlands, lakes, and estuaries. Development alters the physical, geochemical, and biological characteristics of wetland systems. Submerged aquatic vegetation in lakes, ponds and wetlands is impacted through deposition of sediment and particulate pollutant loads, as well as accelerated eutrophication caused by increases in nutrient loadings. Estuaries experience increased sedimentation and pollutant loads, and more extreme salinity swings caused by increased runoff and reduced baseflow. Table 2.2-3 summarizes the effects of urbanization on these receiving environments.

Table 2.2-3
Effects of Urbanization on Other Receiving Environments

Receiving Environment	Impacts
Wetlands	• Changes in hydrology and hydrogeology • Increased nutrient and other contaminant loads • Changes in atmospheric inputs through increased air emissions to the urban airshed • Compaction and destruction of wetland soil • Changes in wetland vegetation • Changes in or loss of habitat • Changes in the community (diversity, richness, and abundance) of organisms • Loss of particular biota • Permanent loss of wetlands
Lakes and Ponds	• Impacts to biota on the lake bottom due to sedimentation • Contamination of lake sediments • Water column turbidity • Aesthetic impairment due to floatables and trash • Increased algal blooms and depleted oxygen levels due to nutrient enrichment, resulting in an aquatic environment with decreased diversity • Contaminated drinking water supplies
Estuaries	• Sedimentation in estuarial streams and SAV beds • Altered hydroperiod of brackish and tidal wetlands, which results from larger, more frequent pulses of fresh water and longer exposure to saline waters because of reduced baseflow • Hypoxia • Turbidity • Bio-accumulation • Loss of SAV due to nutrient enrichment • Scour of tidal wetlands and SAV • Short-term salinity swings in small estuaries caused by the increased volume of runoff which can impact key reproduction areas for aquatic organisms

Source: Adapted from WEF and ASCE, 1998.

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Chapter 3—Stormwater Management Standards

3.1 Overview

This section presents a comprehensive set of minimum performance standards for stormwater management for development activities in Rhode Island. The overall aim is to provide an integrated approach to address both the water quality and quantity problems associated with stormwater runoff.

The goal of the minimum stormwater management standards is to reduce the impact of postconstruction stormwater runoff on the watershed. This can be achieved by:

- Maximizing the use of nonstructural and small-scale management practices.
- Analyzing runoff volume and peak flows to ensure design of practices that effectively control quantity and quality of discharge.
- Using proper construction management practices for soil erosion and sediment control as well as pollution prevention.
- Planning for postconstruction operation and maintenance needs for the life expectancy of the each practice.
- Careful site planning focused on most efficient use of management practices for long-term control, minimization of site impact and postconstruction operation and maintenance.

3.2 Minimum Stormwater Management Standards

The following standards are the minimum stormwater management performance requirements for new development or redevelopment.

Minimum Standard 1: Nonstructural and Small-Scale Upland Management
Nonstructural and small-scale upland management designs must be used to the fullest extent practicable in order to reduce the generation of stormwater runoff and pollutants. Only use structural controls where stormwater runoff cannot be managed via nonstructural and small-scale practices (i.e., pollution hot spots).

Minimum Standard 2: Stormwater Runoff Quality
All stormwater runoff generated from a site must be adequately treated before discharge. Stormwater management systems, which may include both structural stormwater controls and nonstructural practices, must be designed to remove 100% of total suspended solids (TSS) particles that are 70-micron (um) diameter and larger while protecting groundwater quality.

Stormwater management systems comply with this performance standard when:

- Sized to capture and treat the water quality treatment volume, which is defined as 1.0 inch multiplied by the area of impervious surface.

- Selected, designed, constructed, and maintained according to the specific criteria in this manual.
- Hotspot land uses and activities are adequately treated and addressed through the use of appropriate structural stormwater controls and pollution prevention practices.

Minimum Standard 3: Conveyance Protection
Conveyance systems must be designed to provide adequate passage for flows leading to, from, and through stormwater management facilities based on the 10-year, 24-hour storm.

Minimum Standard 4: Overbank Flood Protection
Downstream overbank flood protection must be provided by controlling the postdevelopment peak discharge rate to the predevelopment rate for the 25-year, 24-hour return frequency storm event.

Minimum Standard 5: Extreme Flood Protection
Extreme flood protection must be provided by controlling and safely conveying the 100-year, 24-hour return frequency storm event. Floodplain areas must be preserved whenever possible.

Minimum Standard 6: Downstream Analysis
A downstream hydrologic analysis must be performed to determine whether peak flow impacts are fully attenuated by controlling the 2-, 25- and 100-year events. This analysis must be performed at the outlet(s) of the site, and downstream at each tributary junction to the point(s) in the conveyance system where the area of the portion of the site draining into the system is less than or equal to 10% of the total drainage area above that point.

Minimum Standard 7: Stormwater Abstraction and Groundwater Recharge
Stormwater discharge must be reduced by providing initial abstraction and infiltration capacity for as much of the water quality volume as practicable. In areas where flooding or maintenance of base flow is an issue, groundwater must be abstracted and recharged in a volume equal to the postdevelopment initial abstraction subtracted from the predevelopment initial abstraction volume.

Minimum Standard 8: Construction Erosion and Sedimentation Control
Erosion and sedimentation control practices must be utilized during the construction phase or during any land disturbing activities.

Minimum Standard 9: Pollution Prevention
To the maximum extent practicable, the development project must implement pollutant prevention practices and have a stormwater pollution prevention plan.

Minimum Standard 10: Stormwater Management System Operation and Maintenance
The stormwater management system, including all structural stormwater controls and conveyances, must have an operation and maintenance plan to ensure that it continues to function as designed.

Minimum Standard 11: Stormwater Management Site Plan
All development proposals must include a stormwater management site plan for review by state and local government. A plan must address all of the above minimum standards through compliance with the requirements of this manual.